SPECIFICATION

Docket No. TA-00480

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN that I, Billy R. Carpenter, have invented new and useful improvements in a

Multi-Redundant Inlaid Wiring Harness

of which the following is a specification:

"EXPRESS MAIL" NO. EL506375606US
I hereby certify that this paper or fee is being deposited with the United States Postal Service as "Express Mail Post Office to Addressee" service under 37 C.F.R. § 1.10 on the date indicated below and is addressed to the Hon. Commissioner of Patents and Trademarks, Washington, D.C. 20231. Date of Deposit April 4, 2001 By: Sarah Harner

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention generally relates to electrical system wiring in aircraft and particularly relates to redundant wiring systems inlaid in a composite body.

2. Description of the Prior Art

Electrical power connections in aircraft are typically accomplished using wiring networks made from a conductive material such as metal, whereas control signals may be transmitted using metal wires or optical fibers. Many wires are bundled together in a harness for ease of installation and replacement and to facilitate protection of the wires. The harnesses are located within the interior of the aircraft and may have a single, multiple wire connector at either or both ends, or wires can be separated from the harness as needed along the length of the harness.

Composite materials are being used to construct sections of aircraft, though their use has generally been limited to wing surfaces and exterior panels. Methods of constructing entire aircraft of composites have been proposed, but would involve normal aircraft manufacturing techniques after construction of the main body sections, including running wiring harnesses throughout the interior of the aircraft to provide the necessary power and signal connections. In the past, the wiring harness assemblies are installed in the aircraft after the aircraft body has been assembled. They are typically run in the infrastructure of the aircraft. Such an assembly can cause problems during installation, being subjected to possible shorts generated during installation, and can result in problems after installation because of exposure to wear and tear.

SUMMARY OF THE INVENTION

A multi-redundant inlaid wiring harness provides for alternate electrical or optical pathways in an aircraft wiring system. A plurality or network of wires is inlaid between layers of composite fabric during fabrication of a section of an aircraft. The wires are connected at their ends to computer-controlled buses. The buses select a pathway between the buses from the number of possible pathways. If the selected pathway is later damaged, the buses select a new pathway and reroute the power or signal over the new pathway. Specifically, it is an important feature of the subject invention that the inlaid wiring network is embedded in the composite fabrication layers of the aircraft, minimizing the likelihood of shorted wiring during installation and later due to wear and tear. In addition, the controlled selection and redundancy of the wiring system improves reliability and permits on-the-fly diagnostics and correction of any faults due to a wiring failure.

The wiring system of the subject invention provides multiple pathways for the conveyance of electrical signals throughout the wiring network of the aircraft by providing required information at an entrance gateway to a conduit system, transmitting the information through the conduit system to a exit gateway and then directing the information to its destination. The system relies on the fact that as long as the information is properly entered and exited, the pathway for conveyance is unimportant. This permits any of multiple pathways to be selected and provides for built-in redundancy in the event of failure. By way of example, if certain information is required at the exit gateway and cannot be located, the first analysis would be to determine that the information was, in fact, present at the entrance gateway. Once this assurance is given, then the system will identify an available, functional path to deliver the required information to the exit gateway. This not only permits redundancy not before available in aircraft wiring systems but also simplifies the overall wiring process by tying information to its use requirements rather than to the conduits for delivering the information.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed to be characteristic of the invention are set forth in the appended claims. The invention itself however, as well as a preferred mode of use, further objects and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1 is a perspective view of an aircraft constructed in accordance with the present invention;

Figure 2 is a schematic view of the wiring harness and buses of FIG. 1;

Figure 3 is an exploded perspective view of a section of the aircraft of FIG. 1; and

Figure 4 is perspective view of the section of FIG. 3.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1, aircraft 11 is a vehicle having a structure formed from layers of composite materials. Aircraft 11 is shown as a body having integrated wings and preferably being formed from a one-piece upper section 13 and a one-piece lower section 15. However, the present invention may be applied to wing sections or other vehicles and structures, including those of boats or automobiles. A cockpit controller 17 (see Fig. 2) is located in a cockpit 19 and may be a manual or automated input device for a pilot, such as a switch or a flight-control stick, or computer-controlled , such as in a fly-by-wire system or an autopilot system. Cockpit controller 17 may be an electrical controller or an optical controller. Cockpit controller 17 is connected by input wires 21 to a cockpit bus or gateway 23, cockpit bus 23 having a plurality of connectors for attaching wires 25. The terms "wire" and "wires" are used herein to denote a conduit for power or a signal, and these conduits may be, for example, electrical wire or optical fiber. Cockpit bus 23 is a selector bus for selecting which conduit wires 25 are connected to input wires 21.

Wires 25 are embedded between the layers of sections 13, 15 during fabrication of sections 13, 15. A large number of wires 25 are laid throughout sections 13, 15, though only a few wires 25 are shown in FIG. 1. The important aspect of the system is that a large network of conduit wires 25 are placed in the system during fabrication without specific regard to the use of each conduit wire. However, the number of conduit wires 25 embedded in sections 13, 15 may be limited by considerations such as surface strength and aircraft weight. The conduit wires 25 have terminal ends extending through the outer surface of aircraft 11 toward a wing component 27 that requires electrical power or a control signal, such as a wing-mounted marker light or an electrical servo for moving a flight-control surface. Wires 25 are connected to a wing bus 29 or exit gate, also a selector bus, located near wing component 27. Wing bus 29 is connected to wing component 27 by output wires 31. Bus gateways 23, 29 select a pathway among wires 25 between buses 23, 29 for connecting cockpit controller 17 to wing component 27. Because aircraft 11 is made from composites materials, there is no provision for a common ground throughout aircraft 11, and each power pathway must be accompanied by a path to ground. Typically, one of the available conduit wires will be designated as a common ground path.

A wing controller 33 is mounted in the wing and may be, for example, a position sensor or an accelerometer. Wing controller 33 may be an electrical or an optical controller. Wing controller 33 is connected by input wires 35 to wing bus 29, which is connected to cockpit bus

23 through wires 25. Output wires 37 connect cockpit bus 23 to a cockpit component 39, for example, a read-out instrument or autopilot computer.

Cockpit bus 23 and wing bus 29 are each connected to a central wiring server such as the computer 41. Bus data wires 43 connect each bus 23, 29 to an outer bus 45 located near each bus 23, 29, the outer buses 45 being connected by data wires 47 to computer buses 49. Each computer bus 49 is connected by computer data wires 51 to wiring computer 41. Buses 45, 49 are selector buses for selecting pathways from among data wires 47 to connect computer 41 to buses 23, 29.

FIG. 2 schematically shows the multi-redundant wiring system of FIG. 1. In this figure, cockpit controller 17, wing controller 33, cockpit component 39, and wing component 27 are electrical devices. Cockpit controller 17 is connected by input wires 21 to cockpit bus 23, and wing bus 29 is connected by output wires 31 to wing component 27. Wires 25 extend from cockpit bus 23 to wing bus 29. Wires 25 comprise a large number of wires between buses 23, 29, but only a few are shown in FIG. 2. Wing controller 33 is connected by input wires 35 to wing bus 29, and output wires 37 connect cockpit bus 23 to cockpit component 39. Input wires 21, 35 and output wires 31, 37 each comprises a power wire and a ground wire. Bus data wires 43 connect buses 23, 29 to outer buses 45, and data wires 47 connect each outer bus 45 to a computer bus 49. Computer data wires 51 connect each computer bus 49 to wiring computer 41.

Wiring computer 41 determines the condition and usage of each conduit wire 25, 47 and instructs buses 23, 29, 45, 49 to select particular wires 25, 47 for carrying power or a signal between buses 23, 29 and between buses 45, 49. Buses 45, 49 select pathways to connect computer 41 to buses 23, 29, whereas buses 23, 29 select pathways to connect controllers 17, 33 to components 27, 39. Wiring computer 41 may select the shortest route or the route with the least resistance between buses 23, 29 and between buses 45, 49. However, if a pathway becomes unusable because of damage to aircraft 11 or is needed for a higher-priority use, buses 23, 29, 45, 49 are instructed by computer 41 to reroute the power or signal to another wire 25, 47 to complete the circuit. This multi-redundancy allows for buses 23, 29, 45, 49 to maintain a connection between the buses 23, 29, 45, 49, maintaining the connections between computer 41 and buses 23, 29 and between controllers 17, 33 and components 27, 39.

The following description of the operation of the wiring system of the present invention will focus on the connections and control of the connections between cockpit controller 17 and wing component 27. The operation of the wiring system in connecting wing controller 33 and cockpit component 39 will be the same as that described below, but the direction of the signal through wires 25 would be reversed.

Buses 23, 29 are controlled by wiring computer 41 for switching the connection between buses 23, 29 from one of the wires 25 to another of the wires 25 connected to buses 23, 29. Only one of the wires 25 is a live power connection from cockpit controller 17 to wing component 27 at any time. However, there are a number of redundant wires 25 leading to wing component 27, and buses 23, 29 can switch the connection to an alternate wire. Wiring computer 41 determines the condition and usage of each data wire between outer buses 45 and computer buses 49, and instructs buses 45, 49 to select a particular data cable for transmitting data to buses 23, 29. The data is carried across computer data wires 51 to computer bus 49. The data is routed into the selected wire 47 and arrives at outer bus 45. The data moves from bus 45 to cockpit bus 23 through bus data wires 43. The same type of data connections also provide data for wing bus 29, though separate buses 45, 49 are used. Buses 23, 29 select the appropriate pathway, for example, wire 53, for transmitting power from cockpit controller 17 to wing component 27 and select a ground wire, for example, wire 55.

A pilot or computer actuates cockpit controller 17, and power travels through one input wire 21 to cockpit bus 23, along wire 53, and through wing bus 29 and one output wire 31 to wing component 27. The other output wire 31 provides a path to close the circuit by connecting to the other input wire 21 via buses 23, 29 and wire 55. If wiring computer 41 determines that wire 53 or wire 55 is damaged or otherwise unusable, computer 41 will instruct buses 23, 29 to shift the power or grounding functions to an alternate wire, for example, wire 57. If a data wire 47 is damaged, computer 41 will cause buses 45, 49 to select an alternate data wire 47.

FIG. 3 shows the components used in creating a small surface 59 made from composites and having inlaid wires 25. Outer layers 61 of fabric are placed in a negative mold 63 to form the outside of surface 59. The fabric is preferably woven, high-strength fibers, such as aramid or carbon fiber. Layers 61 could also be unidirectional or chopped fibers. Layers 61 are preferably pre-impregnated with a resin, but resin may be applied through other processes. Wires 25 are laid on top of outer layers 61 in the desired orientation. Because wires 25 are inlaid, it is

required that there be a sufficient number of wires 25 and that wires 25 be placed in the proper locations. Wires 25, input wires 21, output wires 31, and data wires 43 are connected to cockpit bus 23 and wing bus 29. Inner layers 65 of fabric are applied over wires 25 and buses 23, 29, enclosing them in the thickness of surface 59. Inner layers 65 contact outer layers 61 and affix wires 21, 25, 31 and buses 23, 29 in their positions on outer layers 61, there being no space between the components after curing. Though not shown, this process can be repeated to create several layers of wires 25 with layers 65 of fabric between the layers of wires 25. Wires 21, 31 may be directed out of layers 65 for connection to a wing component 27 (FIG. 1) or cockpit controller 17 (FIG. 1), though wires may remain embedded for some distance, as shown in FIG. 4. Alternatively, the ends of wires 25 may be directed through layers 65 of fabric to allow for connection of external buses 23, 29 to wires 25. Also, though not shown, wires 25 may terminate in connectors under layers 65 to which external buses 23, 29 are connected after removing material from layers 65 to expose the connectors. A completed surface 59 containing inlaid wires 25 and buses 23, 29 is shown in FIG. 4.

In assembly, a negative mold 63 is prepared and receives outer layers 61 of fabric that form the outer surface of the finished part, as shown in FIG. 3. Wires 25 and buses 23, 29 are laid in a desired orientation on outer layers 63, and inner layers 65 of fabric are laid in mold 63 over wires 25 and buses 23, 29. Wires 21, 31 for connecting buses 23, 29 to a cockpit controller 17 (FIG. 1) or wing component 27 (FIG. 1) are directed through and out of inner layers 65. Data wires 43 extend out of inner layers 65 to connect buses 23, 29 to wiring computer 41.

Referring to FIGS. 1 and 2, in operation, a computer or pilot actuates a controller 17, 33 to send a signal or electrical power to a component 27, 39. The power or signal passes down input wires 21, 35 to a selector bus 23, 29 and is carried to and from a component 27, 39 through pathways selected from a plurality of wires 25 connected to a second selector bus 23, 29. Buses 23, 29 are preferably controlled by a wiring computer 41 that determines the best pathway from among the plurality of wires 25 for connecting buses 23, 29, computer 41 instructing buses 23, 29 to select particular wires 25. Data from wiring computer 41 is carried to buses 23, 29 by a system of data buses 45, 49, also selector buses, and a plurality of data wires 47. Wiring computer 41 chooses a pathway for the data to reach buses 23, 29 from the data wires 47. If a problem develops in the chosen power or data pathways, buses 23, 29 or 45, 49 are instructed to select a different, undamaged pathway, thus maintaining a closed circuit between controllers 17, 33 and components 27, 39 or computer 41 and buses 23, 29.

The present invention allows for a wiring system of an aircraft to bypass damage caused by material failure or by, for example, projectiles piercing the structure of the aircraft. By automating the process of selecting one of a plurality of pathways to complete a circuit, the pilot is not required to act or be immediately aware that the damage has occurred. The advantage is a system that may prevent a failure causing loss of the aircraft and/or pilot.

While the invention has been shown in only one of its forms, it is not thus limited but is susceptible to various changes and modifications without departing from the spirit thereof. For example, though shown as being controlled by wring computer 41, buses 23, 29 may be semi-autonomous, acting only in pairs to determine the appropriate pathway. Buses 23, 29 may have on-board computers and operational logic for functioning alone or when wiring computer 41 fails or data wires 43, 47, 51 are damaged. A system may be used in which only one bus 23, 29 is a selector bus, the second bus being a non-selector bus in which all wires 25 are connected to wires 21, 31.

An interconnected wire grid would have connections to many buses, allowing a controller to connect to a component through a series of indirect paths. With such a grid, it is also possible to use unused wires for antennae by connecting the wires to transmission sources.